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SIGNATURE COUPLING WITH
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PASSWORD EXPOSURE ELIMINATION FOR DIGITAL SIGNATURE COUPLING WITH A HOST IDENTITY

BACKGROUND

PKI, or Public Key Infrastructure, is a set of operating system and application services that supports public key cryptography. Public key cryptography is an important technology for e-commerce, internet, intranet and other applications requiring “distributed security” (i.e., security in which the participants are not part of the same network and have no common security credentials). Specifically, public key cryptography provides two fundamental operations: encryption and signing. By encrypting electronic data, the goal is for the data to be read only by the intended party. With public key cryptography, a sender can encrypt a message using the specific public key corresponding to the receiver. In turn, only the receiver (using his or her private key) can decrypt the message.

On the other hand, signing is used to authenticate the identity of another party. Again, public key cryptography is involved, but in this instance a message may be encrypted by a sender’s private key. Anyone can decrypt the message with the sender’s corresponding public key, but the identity of the sender is established because the message could only have been encrypted by the sender’s private key.

Public keys are typically packaged as digital certificates, which contain the public key, as well a set of other attributes such as the keyholder’s name, what the keyholder is allowed to do, and under what circumstances the certificate is valid. The X.509 v3 digital certificate is an International Telecommunications Union (ITU) standard defining the format and content of digital certificates. The keyholder’s attributes are cryptographically bound to the public key because the certificate is digitally signed by a Certificate Authority (CA) that issued it. The CA, or issuer, is a trusted entity associated with the keyholder; thus, the certificate’s authenticity and

correctness is vouched for by the issuer's signature.

In certain instances, however, the subject or keyholder identity carried in the digital certificate may not exactly match the keyholder's identity on a particular host system. For example, Figure 1 illustrates an exemplary representation of an X.509 v3 digital certificate 10 and an exemplary system registry 12 for a host server. As can be seen from the subject identity 14 included in the digital certificate, the particular formatting thereof does not correspond to the subject identity 16 in the system registry, even though they are one and the same. In order to establish authorization and gain access, therefore, a flexible means has been developed to include additional attributes within a digital certificate, in addition to the standard attributes. A host-identity mapping extension enables the coupling of a X.509 v3 digital certificate to a host application server, or separately to each of a set of such servers. The host-identity mapping extension may include additional attributes therein to provide proof of identity possession (PIP). For instance, the PIP field can include the password which corresponds to the identity on the host server. If the password and user id are properly accompanied by an appropriate signature, then access to a host server may be achieved.

However, host-identity mapping extensions used in digital certificates are not without drawbacks. This is particularly the case when dealing with an external or third party CA. If the CA is run by an organization outside the host system, then the authenticating secret (password) is exposed to an outside agency which may not necessarily be trustworthy. If the integrity of the CA is compromised, then the password could be used to impersonate the keyholder on the host system. Yet, if the password is not embedded in the extension, the host server must then rely upon the CA to be trustworthy enough to verify the validity of the subject id, without proof of identity possession. It may be appropriate for the host system to honor the host-identity mapping extension of a digital certificate if the certificate is issued by a local

CA, but not honor the extension if the certificate is issued by a public or third party CA. Because most PKI software understands only a binary trust value as applied to CAs (i.e., “trusted” or “not trusted”), the digital signature coupling with host identities can be problematic.

SUMMARY

The above discussed and other drawbacks and deficiencies of the prior art are overcome or alleviated by a method for creating a proof of possession confirmation for inclusion by a certification authority into a digital certificate, the digital certificate for use by an end user. In an exemplary embodiment of the invention, the method includes receiving from the certification authority, in response to a certificate request by the end user, a plurality of data fields corresponding to a target host system, the end user, and a form of proof of identity possession by the end user. The content of the plurality of data fields is analyzed and the accuracy thereof is verified. If the plurality of data fields is verified as accurate, then a signed object is sent to the certification authority, the signed object comprising the proof of possession confirmation.

In a preferred embodiment, the plurality of data fields further includes a host name, a subject identification, a subject public key information and a sealed proof of possession. The content of the plurality of data fields is further analyzed by decrypting a proof of possession structure from the sealed proof of possession. A password and a key identifier are extracted from the proof of possession structure, and the correct key identifier is then calculated from the subject public key information. The accuracy of the plurality of data fields is verified if the host name is matched with an identity of the target host system, the decrypted password is matched with a valid password for the end user, and the decrypted key identifier is matched with the correct key identifier calculated from the subject public key information.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the exemplary drawings wherein like elements are numbered alike in the several Figures:

Figure 1 illustrates representative drawings of information contained in a digital certificate and information contained in a system registry for a host server;

Figure 2 is a block diagram illustrating the relationship between participating entities in certification of a host-identity mapping extension; and

Figure 3 is a flow diagram illustrating a method for creating a proof of possession confirmation for inclusion by a certification authority into a digital certificate, in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

Referring initially to Figure 2, there is shown a block diagram illustrating the relationship between participating entities in the issuance of a certificate with a host-identity mapping extension. An end entity 20 (also referred to as “end user” or “key holder”), has a digital certificate 10 (Figure 1) issued by a certificate authority (CA) 22. As indicated earlier, however, the subject identity 14 for the end entity 20 on the digital certificate 10 may not correspond to the subject identity 16 associated with the end entity’s use of a host system 24. Accordingly, a host identity mapping extension may be incorporated within digital certificate 10, which is of X.509 v3 format. The host identity mapping extension comprises a set of homogeneous structures, each of which may include additional identification attributes such as a host name, a subject identification name (matching, for example, subject identity 16 in a host system registry) and, optionally, a proof of identity possession (PIP) value. The structure of each of the homogeneous set of structures within such a host identity mapping extension may be implemented as shown below using Abstract Syntax Notation 1 (ASN.1) constructs:

```

HostIdMapping ::= SEQUENCE { -- original version
    hostName      [1] IMPLICIT IA5String,
    subjectID      [2] IMPLICIT IA5String,
    proofOfIdPossession  IdProof      OPTIONAL
}

IdProof ::= SEQUENCE {
    secret          OCTET STRING,
    encryptionAlgorithm  OBJECT IDENTIFIER
}

```

With the proliferation of public key authentication technology, each host system 24 will ultimately be associated with a public key certificate. The public key certificate may be published in, and retrieved from, a public network directory 26 (much the same as a person's telephone number is published in telephone directory). In order to facilitate the incorporation of the additional attributes into the host identification mapping extension, the end entity 20 encrypts the proof of identity possession (typically a password) into the host identification mapping extension using the public key of the certificate authority 22 as part of a certificate request message. In response, the CA 22 decrypts the password with its own private key and then re-encrypts it using the public key of the host system 24, which was accessed through public network directory 26.

As also mentioned previously, a problem potentially arises whenever the CA 22 is run by a different organization than the host system 24. The end user 20 may be reluctant to send password information to the CA 22, knowing that if the CA 22 is compromised the password could be used to impersonate the end user 20 on the host system 24. On the other hand, if the host system 24 permits the use of a certificate not having the password for logging in, the host system also has to trust the CA 22 that the subject identification is genuine.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2
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[illegible]

- [illegible]

Once the clearSealedPOP is prepared, the sealedPOP is created by encrypting the clearSealedPOP using the host's public key. Again, the encryption may be accomplished asymmetrically, resulting in a sealedPOP. Or, if done symmetrically (enveloped) in PKCS #7 or Cryptographic Message Syntax format so that the encrypted symmetric key can only be read by the host, then the result is a longSealedPOP. In any case, the sealed proof of possession is placed into the host identity mapping extension, in lieu of the proof of identity possession (PIP) field described earlier, and then sent to the CA as part of the certification request. The sealedPOP may then be placed in the digital certificate as a result of the request.

When the end user presents such a digital certificate for authentication to the host system, the host recovers the password and key identifier by either (1) decrypting the ciphertext directly with the host system's private key, or (2) if enveloping is used, by first decrypting the symmetric key with the host system's private key and then decrypting the ciphertext with the decrypted symmetric key. Once the password is recovered, the host must still establish the absence of a replay attack by verifying that the key identifier matches that of the certificate subject public key.

It will be appreciated that the above described technique allows the password to be hidden from a certificate authority while also preventing a replay attack by an imposter, since the key in the certificate (or certificate request) is used to verify the key identifier in the sealed proof of possession. The host identification mapping extension cannot be used in a new counterfeit certificate, or as part of a counterfeit request for a new certificate, because the key identifier would not match the public key contained in the new certificate.

It will also be appreciated, however, that while the above described technique eliminates a password exposure problem, the password is still coupled with the digital certificate, even if the password is unreadable by the CA. If a user's password is changed over a period of time (as is often the case), the certificate then becomes

unusable and a new one must be requested. Therefore, in accordance with an embodiment of the present invention, a method 100 for creating a proof of possession confirmation for inclusion by a certification authority into a digital certificate is disclosed. In effect, the target host acts as a registration authority (RA) for the certificate authority (CA) by “approving” the host identity mapping extension prior to the issuance of a digital certificate, and then placing a verification of identity or “proof of possession confirmation” signed by the target host system into the digital certificate. The proof of possession confirmation (POP confirmation) does not contain the password information and is used in the certificate in place of the sealed POP.

It should be noted at this point that a “target host system” as described herein need not be a single machine, or even a set of machines with a single network interface. Rather, a target host system is expected to have the property of sharing of non-public key authentication credentials, for some or all of a substantial subset of users, between nodes within the system. Furthermore, the target host system should also publish at least one public key for encryption purposes. For certificate requests containing either sealedPOP or IdProof, it is desirable that there be only one encryption key published for a target system. However, for longSealedPOP, this is unnecessary since the format used therefor includes the identity of the certificate containing the encryption key.

The implementation of method 100 is best understood by referring to the flow diagram in Figure 3. Initially, a certificate request generated by an end user is received by the CA (or the RA associated with the CA) at block 102. The CA, in turn, forwards the data included in the request on to the target host system at block 104. The forwarded data within the proof of possession structure includes: the host name, the subject ID, the SubjectPublicKeyInfo field and the sealed proof of possession field created by the end user. At block 106, the target host matches its identification to the host name. The password and key identifier are then decrypted, as described earlier,

from the sealed proof of possession data. Then, the host calculates the correct key identifier of the Subject Public Key and compares it to the key identifier decrypted from the sealedPOP. Assuming the key identifier is valid, the host then verifies that the decrypted password is valid for the specified user.

If at decision block 108 it is determined that any of the information is not correct, then the certificate request fails. However, if all of the information is correct, method 100 proceeds to block 110 where the host system creates a proof of possession confirmation by sending back to the CA a signed object containing all of the data described in block 104, except for the sealed proof of possession field which contains the password. Finally, at block 112, the signed message is then placed into the host identity mapping extension of the digital certificate by the CA, which digital certificate is then signed by the CA and issued to the user.

The updated ASN.1 definition for the resulting host identity mapping extension, which now includes the proof of possession confirmation, is given by:

```

HostIdMapping ::= SEQUENCE { - - revised definition
    hostName      [1] IMPLICIT IA5String,
    subjectID     [2] IMPLICIT IA5String,

    idproofs CHOICE {
        proofOfIdPossession IdProof,
        sealedPOP           OCTET STRING,
        longSealedPOP [3] IMPLICIT Enveloped Data,
        POPConfirmation     [4] IMPLICIT SignedData - -
                               never in request, only in cert
    } OPTIONAL
}

```

where SignedData and EnvelopedData are defined by PKCS #7 (RFC 2315).

The encrypted content of sealedPOP and longSealedPOP contains the following

structure:

```
clearSealedPOP ::= SEQUENCE {  
    password CHOICE {  
        simple PrintableString,  
        intl UTF8String,  
        ascii IA5String,  
        binary OCTET STRING  
    },  
    keyId KeyIdentifier,  
    padding [0] IMPLICIT OCTET STRING  
OPTIONAL  
}
```

It should be noted that the KeyIdentifier in this instance must be calculated as the digest of the value of the subjectPublicKey bit string, preferably using SHA-1 as the digest algorithm. Other digest algorithms, however, are also contemplated. It should also be noted that the KeyIdentifier will be verified against the key of the certificate, rather than being verified against the SubjectKeyIdentifier extension. Finally, the signed content of the POPConfirmation contains the ConfirmedHostId structure, given below:

```

signedContent ::= ConfirmedHostID

ConfirmedHostID ::= SEQUENCE {
    hostName      [1] IMPLICIT IA5String,
    subjectID     [2] IMPLICIT IA5String,
    CHOICE       {
        keyInfo   SubjectPublicKeyInfo
        KeyID     KeyIdentifier
    }
}

```

Thus configured, the host identity mapping extension included in a digital certificate provides another alternative for proof of possession. When a target host receives a certificate with a signed message in the extension, the host may verify that it signed the message, that it is the host mentioned in the signed message, and that all the fields contained in the signed message match the certificate fields. If successful, the host accepts the credentials presented by the user.

The present invention can include embodiments in the form of computer-implemented processes and apparatuses for practicing those processes. The present invention can also include embodiments in the form of computer program code containing instructions embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, or any other computer-readable storage medium, wherein, when the computer program code is loaded into and executed by a computer, the computer becomes an apparatus for practicing the invention. The present invention can also include embodiments in the form of computer program code, for example, whether stored in a storage medium, loaded into and/or executed by a computer, or transmitted over some transmission medium, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation, wherein, when the computer program code is loaded into and executed by a computer, the computer becomes an apparatus

for practicing the invention. When implemented on a general-purpose microprocessor, the computer program code segments configure the microprocessor to create specific logic circuits.

It is also explicitly contemplated that other data types, in addition to those described above, may be used to encode arguments given within a specific type. For example, changes to tagging and to string type are contemplated. In addition, where feasible, the use of XML instead of ASN.1 may be implemented as an encoding technique.

While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.